THE ROMANCE OF THE HEAVENS

(Continued from page 24)

THE NEBULAR THEORY

§ 2

Nebulæ are dim luminous cloud-like patches in the heavens, more like wisps of smoke in some cases than anything else. Both photography and the telescope show that they are very numerous, hundreds of thousands being already known and the number being continually added to. They are not small. Most of them are immensely large. Actual dimensions cannot be given, because to estimate these we must first know definitely the distance of the nebulæ from the earth. The distances of some nebulæ are known approximately, and we can therefore form some idea of size in these cases. The results are staggering. The more visible surface of some nebulæ is so large that the whole stretch of the solar system would be too small to form a convenient unit for measuring it. A ray of light would require to travel for years to cross from side to side of such a nebula. Its immensity is inconceivable to the human mind.

There appear to be two types of nebulæ, and there is evidence suggesting that the one type is only an earlier form of the other; but this again we do not know.

The more primitive nebulæ would seem to be composed of gas in an extremely rarefied form. It is difficult to convey an adequate idea of the rarity of nebular gases. The residual gases in a vacuum tube are dense by comparison. A cubic inch of air at ordinary pressure would contain more matter than is contained in millions of cubic inches of the gases of nebulæ. The light of even the faintest stars does not seem to be dimmed by passing through a gaseous nebula, although we cannot be sure on this point. The most remarkable physical fact about these gases is that they are luminous. Whence they derive their luminosity we do not know. It hardly seems possible to believe that extremely thin gases exposed to the terrific cold of space can be so hot as to be luminous and can retain their heat and their luminosity indefinitely. A cold luminosity due to electrification, like that of the aurora borealis, would seem to fit the case better.

Now the nebular theory is that out of great "fire-mists," such as we have described, stars are born. We do not know whether gravitation is the only or even the main force at work in a nebula, but it is supposed that under the action of gravity the far-flung "fire-mists" would begin to condense round centres of greatest density, heat being evolved in the process. Of course the condensation would be enormously slow, although the sudden irruption of a swarm of meteors or some solid body might hasten matters greatly by providing large, ready-made centres of condensation.

It is then supposed that the contracting mass of gas would begin to rotate and to throw off gigantic streamers, which would in their turn form centres of condensation. The whole structure would thus form a spiral, having a dense region at its centre and knots or lumps of condensed matter along its spiral arms. Besides the formless gaseous nebulæ there are hundreds of thousands of "spiral" nebulæ such as we have just mentioned in the heavens. They are at all stages of development, and they are visible to us at all angles—that is to say, some of them face directly towards us, others are edge on, and some are in intermediate positions. It appears, therefore, that we have here a striking confirmation of the nebular hypothesis. But we must not go so fast. There is much controversy as to the nature of these spiral nebulæ. Some eminent astronomers think they are other stellar universes, comparable in size with our own. In any case they are vast structures, and if they represent stars in process of condensation, they must be giving birth to huge agglomerations of stars—to star clusters at least. These vast and enigmatic objects do not throw much light on the origin of our own solar system. The nebular hypothesis, which was invented by Laplace to explain the origin of our solar system, has not met with universal acceptance. The explanation offers grave difficulties, and it is best, while

Spiral Nebulæ.

the subject is still being closely investigated, to hold all opinions with reserve. It may be taken as probable, however, that the universe has developed from masses of incandescent gas.

THE BIRTH AND DEATH OF STARS

§ 3

Many astronomers believe that in "variable stars" we have another star, following that of the dullest red star, in the dying of suns. The light of these stars varies periodically in so many days, weeks, or years. It is interesting to speculate that they are slowly dying suns, in which the molten interior periodically bursts through the shell of thick vapours that is gathering round them. What we saw about our sun seems to point to some such stage in the future. That is, however, not the received opinion about variable stars. It may be that they are stars which periodically pass through a great swarm of meteors or a region of space that is rich in cosmic dust of some sort, when, of course, a great illumination would take place.

Variable, New, and Dark Stars: Dying Suns.

Photo: Mount Wilson Observatory.

FIG. 24.—A NEBULAR REGION SOUTH OF ZETA ORIONIS.

Showing a great projection of "dark matter" cutting off the light from behind.

One class of these variable stars, which takes its name from the star Algol, is of special interest. Every third night Algol has its light reduced for several hours. Modern astronomy has discovered that in this case there are really two stars, circulating round a common centre, and that every third night the fainter of the two comes directly between us and its companion and causes an "eclipse." This was until recently regarded as a most interesting case in which a dead star revealed itself to us by passing before the light of another star. But astronomers have in recent years invented something, the "selenium-cell," which is even more sensitive than the photographic plate, and on this the supposed dead star registers itself as very much alive. Algol is, however, interesting in another way. The pair of stars which we have discovered in it are hundreds of billions of miles away from the earth, yet we know their masses and their distances from each other.

We have no positive knowledge of dead stars; which is not surprising when we reflect that a dead star means an invisible star! But when we see so many individual stars tending toward death, when we behold a vast population of all conceivable ages, we presume that there are many already dead. On the other hand, there is no reason to suppose that the universe as a whole is "running down." Some writers have maintained this, but their argument implies that we know a great deal more about the universe than we actually do. The scientific man does not know whether the universe is finite or infinite, temporal or eternal; and he declines to speculate where there are no facts to guide him. He knows only that the great gaseous nebulæ promise myriads of worlds in the future, and he concedes the possibility that new nebulæ may be forming in the ether of space.

The Death and Birth of Stars.

The last, and not the least interesting, subject we have to notice is the birth of a "new star." This is an event which astronomers now announce every few years; and it is a far more portentous event than the reader imagines when it is reported in his daily paper. The story is much the same in all cases. We say that the star appeared in 1901, but you begin to realise the magnitude of the event when you learn that

Photo: Yerkes Observatory.

FIG. 23.—THE GREAT NEBULA IN ORION.

The most impressive nebula in the heavens. It is inconceivably greater in dimensions than the whole solar system.

the distant "blaze" had really occurred about the time of the death of Luther! The light of the conflagration had been speeding toward us across space at 186,000 miles a second, yet it has taken nearly three centuries to reach us. To be visible at all to us at that distance the fiery outbreak must have been stupendous. If a mass of petroleum ten times the size of the earth were suddenly fired it would not be seen at such a distance. The new star had increased its light many hundredfold in a few days.

Photo: Astrophysical Observatory, Victoria, British Columbia.

FIG. 25.—STAR CLUSTER IN HERCULES.

A wonderful cluster of stars. It has been estimated that the distance of this cluster is such that it would take light more than 100,000 years to reach us.

There is a considerable fascination about the speculation that in such cases we see the resurrection of a dead world, a means of renewing the population of the universe. What happens is that in some region of the sky where no star, or only a very faint star, had been registered on our charts, we almost suddenly perceive a bright star. In a few days it may rise to the highest brilliancy. By the spectroscope we learn that this distant blaze means a prodigious outpour of white-hot hydrogen at hundreds of miles a second. But the star sinks again after a few months, and we then find a nebula round it on every side. It is natural to suppose that a dead or dying sun has somehow been reconverted in whole or in part into a nebula. A few astronomers think that it may have partially collided with another star, or approached too closely to another, with the result we described on an earlier page. The general opinion now is that a faint or dead star had rushed into one of those regions of space in which there are immense stretches of nebulous matter, and been (at least in part) vaporised by the friction.

But the difficulties are considerable, and some astronomers prefer to think that the blazing star may merely have lit up a dark nebulæ which already existed. It is one of those problems on which speculation is most tempting but positive knowledge is still very incomplete. We may be content, even proud, that already we can take a conflagration that has occurred more than a thousand billion miles away and analyse it positively into an outflame of glowing hydrogen gas at so many miles a second.

THE SHAPE OF OUR UNIVERSE

§ 4

Our Universe a Spiral Nebulæ.

What is the shape of our universe, and what are its dimensions? This is a tremendous question to ask. It is like asking an intelligent insect, living on a single leaf in the midst of a great Brazilian forest, to say what is the shape and size of

Photo: Lick Observatory.

FIG. 26.—GIANT SPIRAL NEBULA, MARCH 23, 1914.

This spiral nebula is seen full on. Notice the central nucleus and the two spiral arms emerging from it in opposite directions. Is matter flowing out of the nucleus into the arms or along the arms into the nucleus? In either case we should get two streams in opposite directions within the nucleus.

the forest. Yet man's ingenuity has proved equal to giving an answer even to this question, and by a method exactly similar to that which would be adopted by the insect. Suppose, for instance, that the forest was shaped as an elongated oval, and the insect lived on a tree near the centre of the oval. If the trees were approximately equally spaced from one another they would appear much denser along the length of the oval than across its width. This is the simple consideration that has guided astronomers in determining the shape of our stellar universe. There is one direction in the heavens along which the stars appear denser than in the directions at right angles to it. That direction is the direction in which we look towards the Milky Way. If we count the number of stars visible all over the heavens, we find they become more and more numerous as we approach the Milky Way. As we go farther and farther from the Milky Way the stars thin out until they reach a maximum sparseness in directions at right angles to the plane of the Milky Way. We may consider the Milky Way to form, as it were, the equator of our system, and the line at right angles to point to the north and south poles.

Photo: Mount Wilson Observatory.

FIG. 27.—A SPIRAL NEBULA SEEN EDGE-ON.

Notice the lens-shaped formation of the nucleus and the arm stretching as a band across it. See reference in the text to the resemblance between this and our stellar universe.

Our system, in fact, is shaped something like a lens, and our sun is situated near the centre of this lens. In the remoter part of this lens, near its edge, or possibly outside it altogether, lies the great series of star clouds which make up the Milky Way. All the stars are in motion within this system, but the very remarkable discovery has been made that these motions are not entirely random. The great majority of the stars whose motions can be measured fall into two groups drifting past one another in opposite directions. The velocity of one stream relative to the other is about twenty-five miles per second. The stars forming these two groups are thoroughly well mixed; it is not a case of an inner stream going one way and an outer stream the other. But there are not quite as many stars going one way as the other. For every two stars in one stream there are three in the other. Now, as we have said, some eminent astronomers hold that the spiral nebulæ are universes like our own, and if

THE SOLAR SYSTEM				
MERCURY	36 0	0 24	3030	0
VENUS	67 2	0 62	7700	0
EARTH	92 9	1 00	7918	1
MARS	141 5	1 88	4230	2
JUPITER	483 3	11 86	86500	9
SATURN	886 0	29 46	73000	10
URANUS	1781 9	84 02	31900	4
NEPTUNE	2971 6	164 78	34800	1
SUN	——	——	866400	——
MOON	——	——	2113	——

FIG. 28.

we look at the two photographs (figs. 26 and 27) we see that these spirals present features which, in the light of what we have just said about our system, are very remarkable. The nebula in Coma Berenices is a spiral edge-on to us, and we see that it has precisely the lens-shaped middle and the general flattened shape that we have found in our own system. The nebula in Canes Venatici is a spiral facing towards us, and its shape irresistibly suggests motions along the spiral arms. This motion, whether it is towards or away from the central, lens-shaped portion, would cause a double streaming motion in that central portion of the kind we have found in our own system. Again, and altogether apart from these considerations, there are good reasons for supposing our Milky Way to possess a double-armed spiral structure. And the great patches of dark absorbing matter which are known to exist in the Milky Way (see Fig. 24, p. 71) would give very much the mottled appearance we notice in the arms (which we see edge-on) of the nebula in Coma Berenices. The hypothesis, therefore, that our universe is a spiral nebula has much to be said for it. If it be accepted it greatly increases our estimate of the size of the material universe. For our central, lens-shaped system is calculated to extend towards the Milky Way for more than twenty thousand times a million million miles, and about a third of this distance towards what we have called the poles. If, as we suppose, each spiral nebula is an independent stellar universe comparable in size with our own, then, since there are hundreds of thousands of spiral nebulæ, we see that the size of the whole material universe is indeed beyond our comprehension.

In this simple outline we have not touched on some of the more debatable questions that engage the attention of modern astronomers. Many of these questions have not yet passed the controversial stage; out of these will emerge the astronomy of the future. But we have seen enough to convince us that, whatever

STAR DISTANCES	
STAR	DISTANCE IN LIGHT-YEARS
POLARIS	76
CAPELLA	49·4
RIGEL	466
SIRIUS	8·7
PROCYON	10·5
REGULUS	98·8
ARCTURUS	43·4
∝ CENTAURI	4·29
VEGA	34·7
SMALLER MAGELLANIC CLOUD	32,600 (ESTIMATED)
GREAT CLUSTER IN HERCULES	108,600 (ESTIMATED)

FIG. 29.

The above distances are merely approximate and are subject to further revision. A "light year" is the distance that light, travelling at the rate of 186,000 miles per second, would cover in one year.

advances the future holds in store, the science of the heavens constitutes one of the most important stones in the wonderful fabric of human knowledge.